CHAPTER 8

INSTALLATION OF CPU AND HEAT SINK

INTRODUCTION

The processor is commonly known as central processing unit or CPU. It is an electronic circuit which executes computer programs containing a processing unit and a control. A central processing unit (CPU) processes the instructions by performing the basic arithmetical, logical, and input/output operations of the system. Although the form and design of CPUs is changing with generation but its main working principle remains the same.

CPU BASICS

In 1971, the first microprocessor Intel 4004 was invented. It was a 4 bit calculation device with a speed of 108 kHz. A microprocessor is also known as a central processing unit in which a numbers of peripherals are fabricated on a single chip.

Architecture of Microprocessor

A microprocessor is a single integrated circuit (IC) chip. A number of useful functions are integrated and fabricated on a single silicon semiconductor chip.

The system bus consists of data bus, address bus, and control bus for transfer of data and instructions in a proper manner. The central processing unit consists of arithmetic logic unit (ALU), registers, and control unit. Based on the registers, the generations

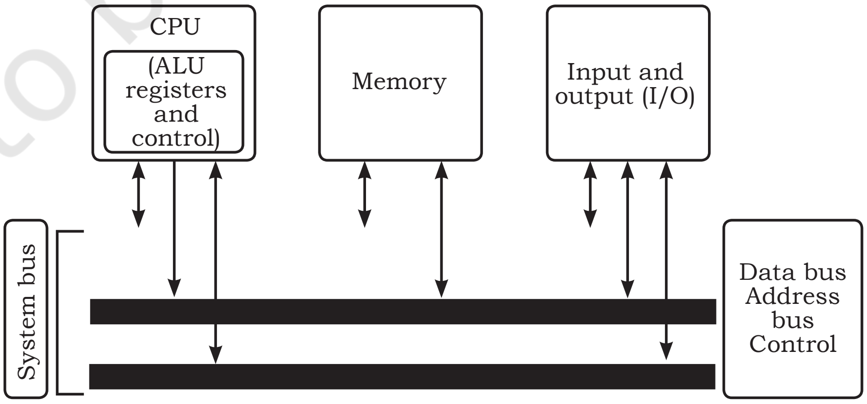

Fig. 8.1: Architecture of CPU

of microprocessors can be classified. A microprocessor consists of general purpose registers and special types of registers to execute instructions and to store the address or data while running the program. The ALU computes all arithmetic as well as logic operations on data and specifies the size of microprocessor like 16 bit or 32 bit.

The memory unit holds the program as well as data and is divided into processor, primary, and secondary memory. The input and output unit interfaces the I/O peripheral devices to microprocessor for accepting and sending information.

Generations of Microprocessors

1st generation: This was the period during 1971 to 1973 of microprocessor's history. In 1971, INTEL created the first microprocessor 4004 to run at a clock speed of 108 KHz.

2nd generation: During the period from 1973 to 1978 very efficient 8-bit microprocessors were implemented like Motorola 6800 and 6801, INTEL-8085, and Zilogs-Z80 which were of this generation.

3rd generation: During the period from 1979 to 1980, 16 bit processors were designed using HMOS technology. INTEL 8086/80186/80286 and Motorola 68000 and 68010 were developed. Speeds of these processors was four times better than the 2nd generation processors.

4th generation: From 1981 to 1995, 32 bit microprocessors were developed by using HCMOS fabrication. INTEL-80386 and Motorola's 68020/68030 were the processors of this generation.

5th generation: From 1995, high-performance and high-speed processors that make use of 64-bit processors were designed. Such processors include Pentium, Celeron, dual and quad core processors.

Some of the fifth generation of processors with their specifications, are briefly explained below:

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Fig. 8.2: Intel Celeron processor

Intel Celeron

This was introduced in April 1998. It refers to a range of Intel's X86 CPUs for value personal computers. It is based on Pentium 2 and can run on all IA-32 computer programs.

Pentium

This was introduced on March 2 in 1993 after Intel 486, the 4 here in 486 indicates the fourth generation. Pentium refers to Intel's single core x86 microprocessor which is based on the fifth generation micro-architecture. This processor's name was derived from the Greek word 'penta' meaning 'five'. The Pentium MMX with a data bus of 64 bits was developed in 1996. More improved versions of pentium processors were designed from the year 2000.

Fig. 8.3: Pentium processor

Xeon

This is a 400 MHz Pentium processor from Intel for use in workstations and enterprise servers. This processor is designed for multimedia applications, engineering graphics, internet, and large data base servers.

Fig. 8.4: Xeon processor

Functions of a CPU

A CPU or processor carries out certain instructions and manipulates data. The main function of a CPU is to execute a sequence of stored instructions called a program. It can execute only machine code and fetches the machine coded instructions from memory and executes them. CPU processes instructions in four steps—fetch, decode, execute, and write back.

Fetch: The CPU reads data and instruction from memory.

Decode: The data and instructions are decoded to determine what action is required.

Execute: The instructions are executed by performing arithmetic or logical operation on data.

Write: The result of an execution is written to memory or an I/O module.

Concept of program execution

The instructions to be executed by a computer are loaded in sequential locations in its main memory. To execute instructions, the CPU fetches one instruction at a time and performs the functions specified. Instructions are fetched from successive memory locations until the execution of a branch or a jump instruction.

The CPU keeps track of the address of the memory location where the next instruction is located through the use of a dedicated CPU register, referred to as the program counter (PC). After fetching an instruction, the contents of the PC are updated to point at the next instruction in sequence.

For simplicity, let us assume that each instruction occupies one memory word. Therefore, execution of one instruction requires the following three steps to be performed by the CPU:

1. fetch the contents of the memory location pointed out by the PC (program counter). The instructions are stored in the instruction register (IR).
2. increment the contents of the PC by 1.
3. carry out the actions specified by the instruction stored in the IR.

The first two steps are the fetch phase and step three is the execution phase. Fetch cycle involves reading of the next instruction from the memory into the CPU and updating the contents of the program counter. In the execution phase, it interprets the opcode and performs the indicated operation. The instruction fetch and execution phase together are known as the instruction cycle. The instruction cycle is shown in the Figure 8.5.

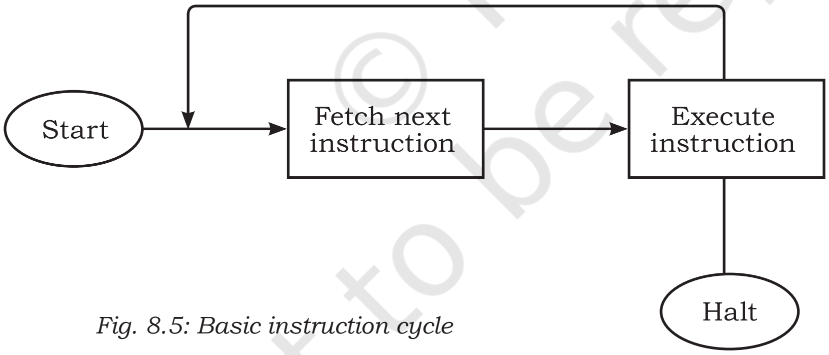


Fig. 8.5: Basic instruction cycle

In cases where an instruction occupies more than one word, step one and step two can be repeated as many times as necessary to fetch the complete instruction. In these cases, the execution of an instruction may involve one or more operands in memory, each of which requires a memory access. Further, if indirect addressing is used, then additional memory accesses are required.

Major components of the CPU

The three major components of the CPU are — arithmetic and logic unit (ALU), control unit (CU), and registers.

Arithmetic and logic unit (ALU)

This performs arithmetic and logical operations. For example, it can add together two binary numbers either from memory or from some of the CPU registers.

Control unit

This controls the action of the other computer components so that instructions are executed in the correct sequence.

Registers

These are temporary storage inside the CPU. It is internal memory of CPU which can read and write at a high speed. It is used to hold data and instructions temporarily while processing. It also holds the location of the last instruction. With this it can find the location of the next executable instruction.

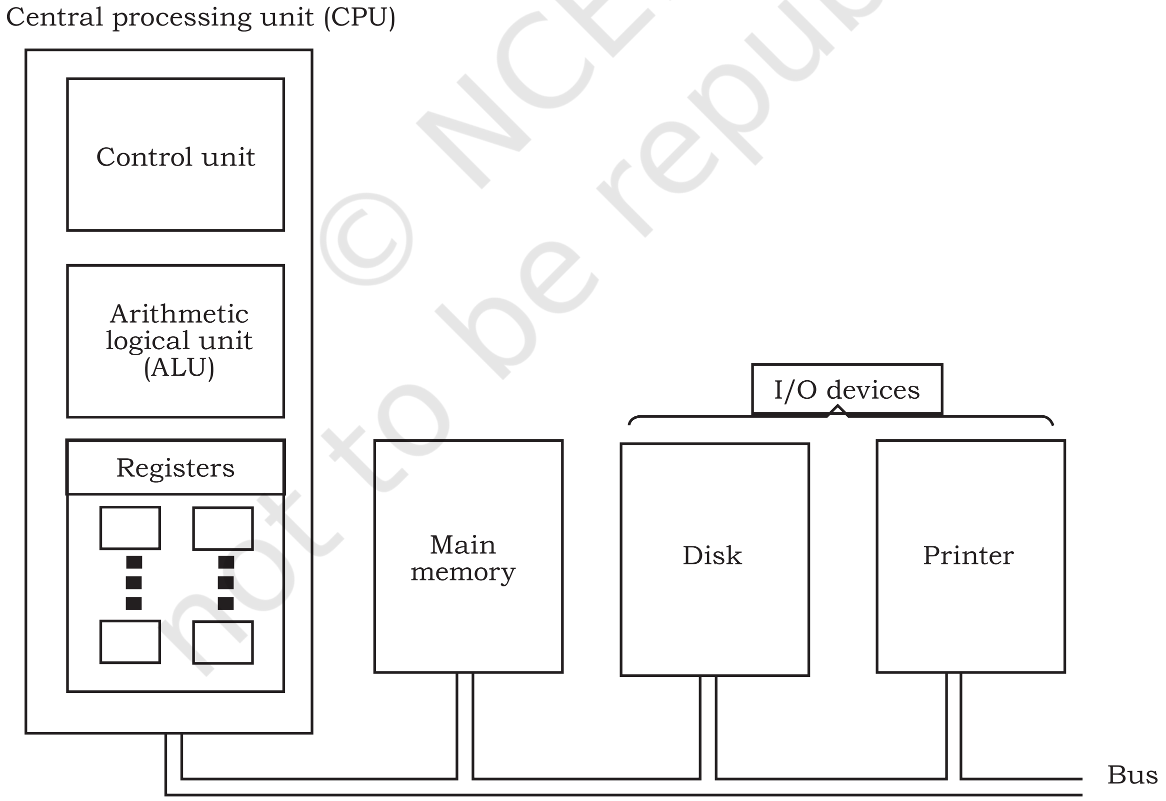


Fig. 8.6: Major components of the CPU

Register organisation

There are a variety of CPU registers to control the operation of the CPU. The four most commonly used registers, essential for instruction execution are listed below.

Program counter (PC)

It contains the address of an instruction to be fetched. The program counter is updated by the CPU after each instruction fetched so that it always points to the next instruction to be executed. A branch or skip instruction will also modify the contents of the PC.

Instruction register (IR)

It contains the instruction most recently fetched. The fetched instructions are loaded into an IR, where the opcode and operand specifiers are analysed.

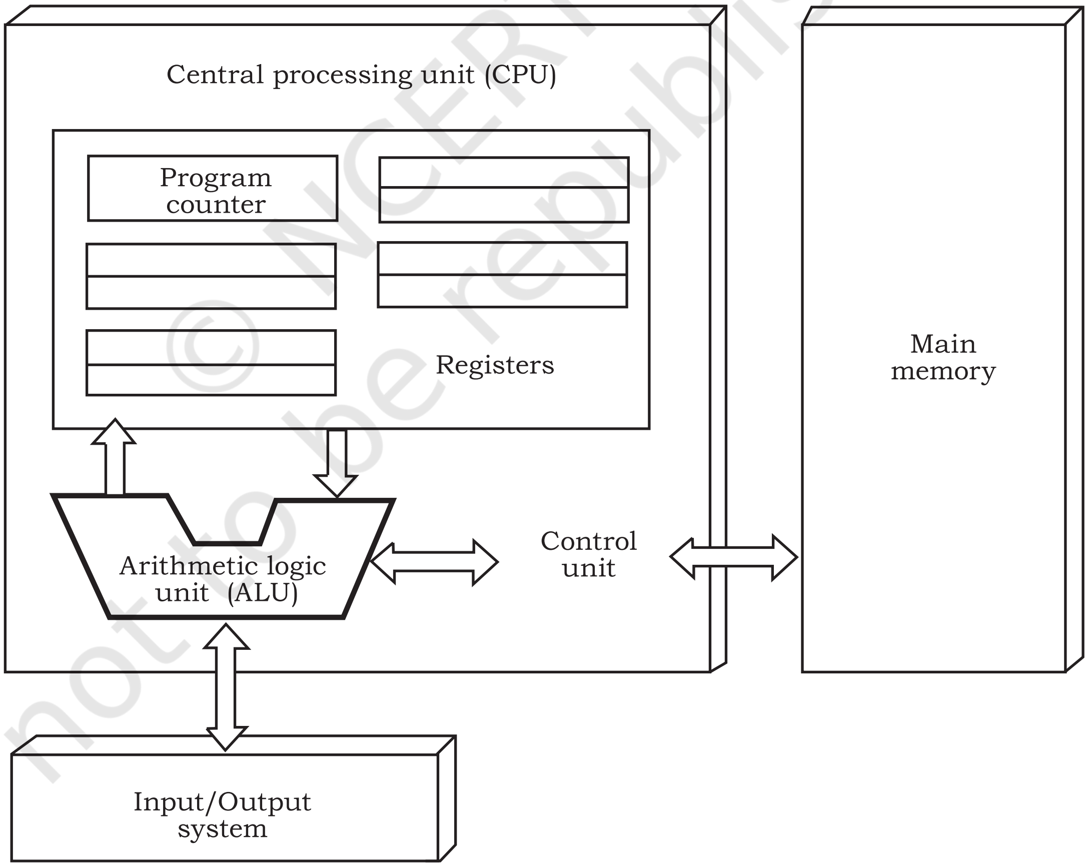


Fig. 8.7: Organisation of register

Memory address register (MAR)

It contains the address of a location of main memory from where information has to be fetched or stored. Contents of MAR are directly connected to the address bus.

Memory buffer register (MBR)

It contains a word of data to be written to memory or the word most recently read. Contents of MBR are directly connected to the data bus. It is also known as memory data register (MDR).

Apart from these specific registers, we may have some temporary registers which are not visible to the user. As such, there may be temporary buffering registers at the boundary to the ALU; these registers serve as input and output registers for the ALU and exchange data with the MBR and user visible registers.

System bus

The CPU is connected to the rest of the system through system bus. Through system bus, data, or information gets transferred between the CPU and the other components of the system. The system bus may have three components:

Data bus

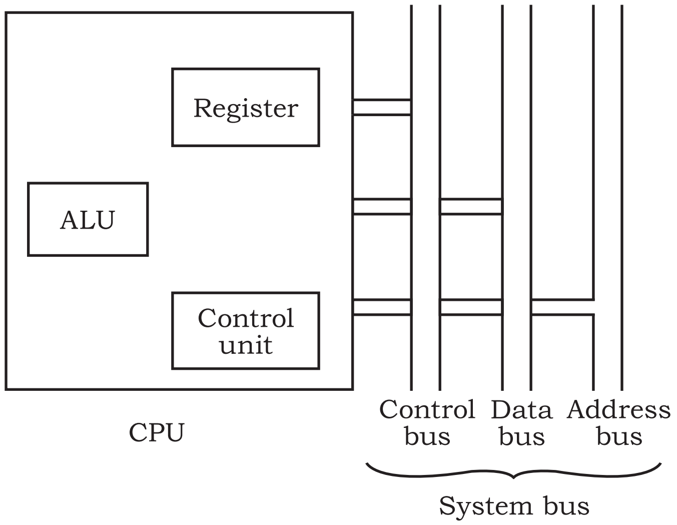
This is bidirectional, used to transfer the data between main memory and CPU. It determines the size of the data transferred between the processor and memory or I/O device. It refers to the size of the data bus in bits.

Address bus

This is unidirectional and used to access a particular memory location by putting the address of the memory location. It determines the size of the memory addressable by the processor

Control bus

This is used to provide different control signals generated by the CPU to the different parts of the system.



It indicates the type of action taking place on the system bus. For example, memory read is a signal generated by the CPU to indicate that a memory read operation has to be performed. Through the control bus, this signal is transferred to the memory module to indicate the required operation.

The following Figure 8.8 shows the internal organisation of the CPU.

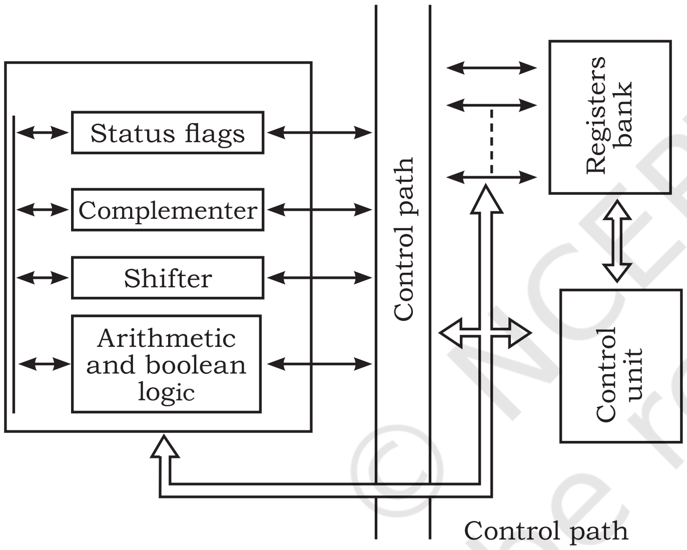


Fig. 8.8: Internal organisation of CPU

CPU Features

There are many features that influence the performance of a processor:

Processor speed/clock rate

The clock speed of a processor is the number of instructions it can process in one second. It is the speed of the clock that drives the processor. The first processor 8088 was released at 4.77 MHz. Modern processors run at speeds of 2 GHz or greater. A CPU with a clock speed of 3.0 GHz can process three billion instructions per second. A faster CPU uses more energy and generates more heat.

CPU cores

A CPU can contain one or more processing units. Each unit is called a core. Modern PC processors are multicore. CPUs with multiple cores have more power to run multiple programs at the same time. Each core is fully functional, meaning each core contains an ALU, control unit, and registers. A dual core has two cores, quad core has four cores.

For example, Intel Core i7 chips perform better than i5 chips which perform better than i3 chips. Intel Core i3 processors are dual core processors, while i5 and i7 chips are quad core processors.

Cache

This is a small memory of CPU closer to the CPU than RAM. It is used to temporarily hold instructions and data that the CPU is likely to reuse. The CPU control unit automatically checks cache for instructions before requesting data from RAM. This saves fetching the instructions and data repeatedly from RAM. RAM is a relatively slow memory than cache. Cache memory is fast and takes less time to transfer data and instructions to the CPU. More cache can hold more data to make the processing in the CPU faster. There are three types of cache memory—Level 1 (L1), Level 2 (L2), and Level 3 (L3).

Level 1 (L1) is the part of the CPU chip itself. It is the smallest and the fastest to access. Its size is often restricted to between 8 KB and 64 KB. Level 2 (L2) and Level 3 (L3) caches are bigger than L1. They are extra caches built between the CPU and the RAM. Sometimes L2 is built into the CPU with L1. L2 and L3 caches take slightly longer to access than L1. A computer with more L2 and L3 cache memory can run faster. Modern CPUs have 512 KB L1 cache built in and 1024 KB or 2048 Kb(2 Mb) of L2 cache memory.

Cache is more expensive than RAM. It is allocated less physical space than RAM which is usually larger and less expensive. Each CPU core has its own L1 cache, but may share L2 and L3 caches.

Bandwidth of data bus

The data bus connects the CPU to memory as well as all the storage, input/output, and communication devices. The processor uses data bus to transfer data between itself and the system memory (RAM and ROM) and the secondary devices. The size in bits determines how many characters are needed to transfer at a time. They are usually 8, 16, or 32-bits wide. An 8 bit data bus transfers one character at a time, a 16 bit data bus transfers two characters at a time, and a 32 bit data bus transfers four characters at a time. Thus, performance of a CPU also depends on the size of the data bus.

Memory

This is the area where the computer stores data and instructions. It provides the CPU with instructions. There are different types of memory and each one plays an important role in the running of a computer system. It is sometimes called primary memory or main memory or RAM. More amount of RAM can run the computer faster and also can handle the large programs. It is the main place for storing instructions and data when a program is being executed. Program data is copied into RAM before the CPU can run the program.

Word size

The word size of the machine is how many bits the CPU can manipulate in one go. Each unique memory location in RAM holds one word of information. Every memory location has an unique address. RAM also has a word size measured in bits to indicate the size of the memory location.

Types of CPU

CPU can be categorised on the basis of its processing power as 32 bit or 64 bit and can also be classified on the basis of brands (Intel and AMD).

32 bit and 64 bit CPU

CPUs are identified as either 32 bit or 64 bit. The amount of data that a CPU can manipulate with one machine code instruction or transfer over a bus is measured in bits. The CPU specification is 32 bit, 64 bit, or 128 bit. A CPU with a 64 bit word size can process 64 bits using one single machine code instruction. This is twice as many bits as a 32 bit

CPU. Increase in the word size means more data can be manipulated at a greater speed. It also means that the CPU can keep track of a larger range of memory locations.

A 32 bit CPU supports a 32 bit address bus and can address 232 memory locations or 4 GB of RAM. A 64 bit CPU supports a 64 bit address bus and can address 264 memory locations.

Operating systems and applications that are 64 bit specific cannot run on a 32 bit processor. The 64 bit operating systems can run only on 64 bit CPUs. If you want to directly address more than 4 GB of RAM, you need both a 64 bit CPU and a 64 bit operating system.

Intel and AMD Processors

There are two primary manufacturers of computers: Intel and Advanced Micro Devices (AMD).

Intel

It is the largest seller of CPUs, selling about 80 percent to 85 percent of all CPUs. It manufactures other products as well, including chipsets, motherboards, memory, and SSDs.

AMD

It is the only significant competition to Intel for CPUs and it sells about 10 percent to 15 percent of all CPUs. It also manufactures other products including graphics processors, chipsets, and motherboards.

Processor technologies

These might be used by AMD only, by Intel only, or by both vendors. These technologies are used to help distinguish different processors from each other in terms of performance or features.

When we talk about processor technologies, we can classify them into:

Overclocking: For most motherboards and processors, you can override the default frequencies by changing a setting in BIOS setup. Running a motherboard or processor at a higher speed than the manufacturer suggests, is called overclocking. This is not recommended because the speed is not guaranteed to be stable. Also, know that running a processor at a higher than recommended speed can result in overheating, which can damage the processor. Dealing with overheating is a major concern when overclocking a system.

VRM: A CPU is a collection of transistors. These transistors work at a specific voltage level. If excessive voltage is supplied to the transistor, it will burn off. Hence, the motherboard manufacturers have to take special care of the CPU voltages.

Throttling: Most motherboards and processors offer some protection against overheating so that if the system overheats, it will throttle down or shut down to prevent the processor from being affected.

Hyper-threading (HT Technology): It is a technology developed by Intel for processing two execution threads within a single processor. Essentially when HT Technology is enabled in the system, BIOS and the processor is running a multi-threaded application and the processor is emulating two physical processors.

Processor difference

Although Intel and AMD processors share two common architectures— x86 (used for 32 bit processors and for 64 bit processors, running in 32 bit mode) and x64 (an extension of x86 that enables larger files, larger memory sizes, and more complex programs), these processor's family differ in many ways from each other, including:

1. different processor sockets
2. different types of microcode
3. differences in dual-core and multi-core designs
4. cache sizes
5. performance versus clock speed

NOTES

The various activities that a microprocessor performs, such as storing data, doing arithmetic calculations (addition, subtraction, multiplication, division, etc.), are the result of instructions given to the CPU in the form of sequences of 0s and 1s. Microprocessors are designed to carry out a large number of instructions and all the instructions may be represented by different sequences of 0s and 1s. Each instruction is represented by a unique set of 0s and 1s.

The internal structure of a typical CPU consists of circuits which form a number of registers (the typical number is 16), an arithmetic unit for carrying out arithmetic operations, a logic unit, and a control unit.

Practical Activity

Installation of CPU

The CPU and motherboard are sensitive to electrostatic discharge. So place them on a grounded anti-static mat and wear an anti-static wrist strap while handling the CPU. When handling a CPU, do not touch the CPU contacts at any time. The CPU is secured to the socket on the motherboard with a locking assembly.

Thermal compound which is used to conduct heat away from the CPU is applied on top of the CPU. In case of an old CPU, first clean the top of the CPU and then apply the thermal compound. Clean the top of the CPU and the base of the heat sink with isopropyl alcohol and a lint free cloth. This removes the old thermal compound. Then apply a new layer of thermal compound.

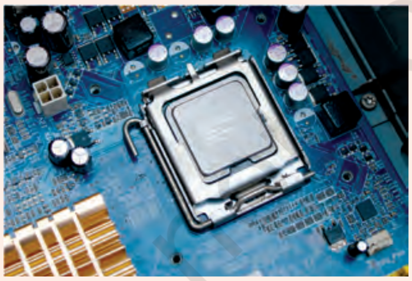


Fig. 1: Installing CPU on the motherboard

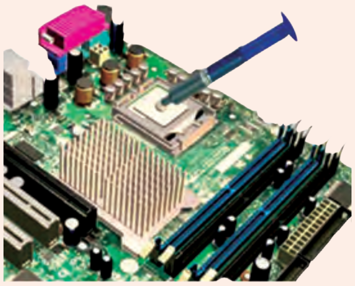


Fig. 2: Applying thermal compound on CPU

CPU heat sink

This is an important component in the modern computer. It is an attachment for a chip that prevents the chip from overheating. The components that generate the most heat in your computer are the CPU (central processing unit) and the power supply. These components need to be kept within a specified temperature range to prevent overheating, instability, malfunction, and damage leading to a shortened component lifespan. They always have some cooling usually in the form of a fan.

A heat sink is a device that incorporates either a fan or some other means, to keep a hot component such as a processor, cool. It is made from metal, which serves as the thermal conductor that carries heat away from the CPU. It uses either copper, aluminum, or a combination of the two in order to move heat from the base of the cooler through heat pipes to the heat sink. A fan then blows air through the heat sink to move the heat into the air, and then out of the system, effectively keeping the CPU within safe operating temperatures.

A liquid cooling system essentially applies the same idea but replaces the copper heat pipes with tubes filled with a thermally conductive liquid that is pumped to a radiator. Copper is a very good thermal conductor with a thermal conductivity of 400 W/mK. Aluminum has a thermal conductivity of 235 watts per Kelvin per meter (W/mK), but is lighter than copper. A heat sink is attached to the motherboard, its weight puts stress on

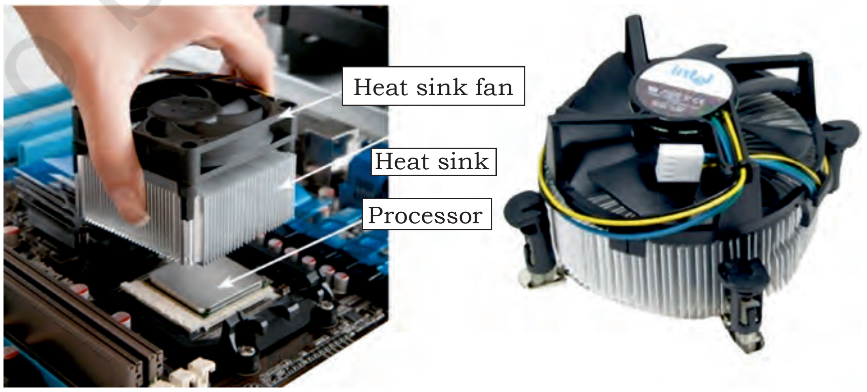


Fig. 8.9: Heat sink with cable and connector

the motherboard. The light weight of an aluminum heat sink puts a little weight and stress on the motherboard.

A heat sink is designed to increase the surface area in contact with the cooling fluid surrounding it, such as the air, thus allowing it to remove more heat per unit time. Other factors which improve the thermal performance of a heat sink are the approach air velocity, choice of material, usually an aluminum alloy due to its high thermal conductivity values (229 W/m°K), fin (or other protrusion) design, and surface treatment.

The heat conducted from the processor goes out through the heat sink. A fan inside the computer moves air across the heat sink and out the computer. Most computers also have an additional fan installed directly above the heat sink to help properly cool the processor. Heat sinks with these additional fans are called active heatsinks, while those with the single fan are called passive heat sinks. The most common fan is the case fan, which draws cool air from outside the computer and blows it through the computer, expelling the hot air out of the rear.

Practical Activity

Installation of heat sink

Heat sink and fan assembly

Heat sink is a cooling device. The heat sink draws heat away from the CPU. The fan moves the heat away from the heat sink. The assembly has a 3-pin power connector. Figure 1 shows the cable and the motherboard connector for the heat sink.

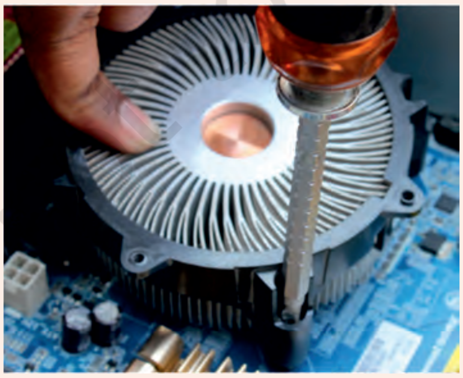


Fig. 1: Screwing the heat sink

To install a CPU fan and heat sink, follow these steps:

- align the heat sink and fan assembly with the holes on the motherboard.
- screw in the heat sink.

Check Your Progress

A. Multiple choice questions

1. Which was the first microprocessor?
   (a) Intel 4004 (b) Intel 8088
   (c) Intel 8086 (d) Intel
2. Which of the following is not a system bus?
   (a) Address bus (b) Data bus
   (c) Control bus (d) Memory bus
3. Which of the following is not a part of a CPU?
   (a) Arithmetic logic unit (b) Memory
   (c) Control unit (d) Registers
4. Which of the following register points to the next instruction to be executed?
   (a) Program counter (b) Instruction register
   (c) Memory address register (d) Memory buffer register
5. The clock speed of recent processor is measured in ______________.
   (a) MHz (b) KHz
   (c) GHz (d) Hz
6. The memory data bus width in Pentium processor is ______________.
   (a) 16 bit (b) 32 bit
   (c) 64 bit (d) 8 bit
7. Copper and aluminum is used to prepare heat sink because of ______________.
   (a) low thermal conductivity and heavyweight
   (b) high thermal conductivity and lightweight
   (c) low thermal conductivity and lightweight
   (d) high thermal conductivity and heavyweight

B. Fill in the blanks

1. A 32-bit CPU can address __________ memory locations.
2. A 64-bit CPU can address __________ memory locations.
3. Hyper threading technology supports processing __________ execution threads within a single processor.
4. Contents of MAR is directly connected to the ____________ bus.
5. Contents of MBR is directly connected to the ____________ bus.

6. Copper has a thermal conductivity of _______________.
7. A heat sink is attached on the ____________.
8. Heat sinks with additional fans are called ____________.
9. Heat sinks with a single fan are called ____________.

C. Short question answers

1. What are the major components of a CPU?
2. What is the overall function of a processor's control unit?
3. What are the basic tasks performed by a CPU?
4. Why registers are used in a CPU?
5. Name the four registers in a CPU.
6. Explain the use of the four registers—program counter, instruction register, memory address register, and memory buffer register.
7. Give and explain the instruction cycle state diagram.
8. Explain the system bus briefly.
9. What is a heat sink?
10. Why are copper and aluminum used to prepare a heat sink?
11. What is the thermal conductivity of aluminum?

NOTES